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## EUROPEAN PATENT APPLICATION

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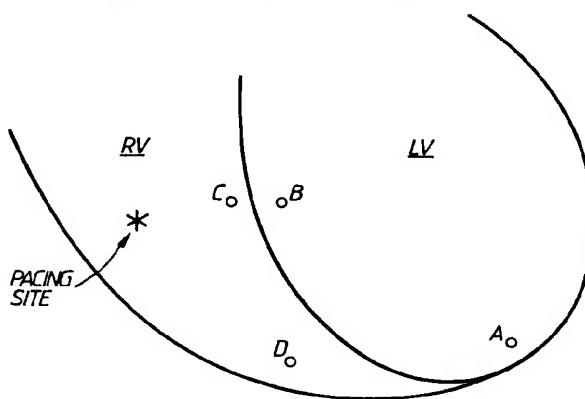
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### **(54) Apparatus for recognition of ventricular tachycardia and ventricular fibrillation and for termination thereof.**

(57) Apparatus for the automatic recognition of ventricular tachycardia and ventricular fibrillation compares pulse sequences which are obtained when sensing at at least one position on each ventricular epicardial surface of a heart. Changes in the sequence of activations and in the timing from pulsing at one sensor position to next pulsing at that position will indicate both ventricular tachycardia and ventricular fibrillation to enable a response to be made to restore to a pulse sequence representing the normal ventricular activity of the heart.



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1    APPARATUS FOR RECOGNITION OF VENTRICULAR TACHYCARDIA AND  
     VENTRICULAR FIBRILLATION AND FOR TERMINATION THEREOF

5    This invention relates to apparatus for  
recognition of ventricular tachycardia and ventricular  
fibrillation from epicardial electrogram timings and for  
termination thereof.

10   Ventricular fibrillation is defined as a condition  
characterised by fibrillary electrical activity of the  
ventricular muscle, the electrical impulses traversing  
the ventricles so rapidly that coordinated contractions  
cannot occur. This must be distinguished from  
ventricular tachycardia which may be defined as a rapid  
(greater than 110 beats per min) cardiac rhythm  
originating in the ventricles. If sustained, it is  
usually synchronised in terms of overall ventricular  
contraction. Both should be differentiated from the  
normal situation of sinus rhythm where the heart's rhythm  
is controlled by depolarisation originating from the  
sinus node and which spread sequentially through the  
atria, the AV node, the His-Purkinje system and  
ventricular myocardium.

25   It is an object of the invention to provide  
apparatus for recognizing both ventricular tachycardia  
and ventricular fibrillation to be used with means for  
responding to both these conditions to restore normal  
heart rhythm.

30   According to the present invention, there is  
provided apparatus for the automatic recognition of  
ventricular tachycardia and ventricular fibrillation  
comprising:

at least two sensors for attachment of at least  
one sensor to each ventricular epicardial surface of a  
heart;

35   signal paths connecting the sensors to programmed  
means for detecting a pulse sequence representing the  
ventricular electrical activity of the heart and for  
comparing the pulse sequence detected with that

1 representing the electrical activity of the heart during  
normal ventricular rhythm of the heart; and  
means for converting the detected pulse sequence  
into a form which will be useful for providing a  
5 corrective response to a pulse sequence representing the  
electrical activity of the heart during abnormal  
ventricular rhythm of the heart. The apparatus will  
generally be used in association with means for supplying  
to the heart stimuli to restore normal rhythm to the  
10 heart following detection of abnormal ventricular rhythm,  
in which case there may be no need for converting the  
detected pulse sequence into a readable form or other  
form, such as audible form, which makes a pulse sequence  
representing electrical activity of the heart during  
15 abnormal ventricular rhythm of the heart to be  
identified.

For a better understanding of the invention and to  
show how the same can be carried into effect, reference  
will now be made, by way of example only, to the  
20 accompanying drawings wherein:-

FIGURE 1 shows schematically an arrangement of  
four ventricular activation sites;

FIGURE 2 shows the electrograms obtained from the  
four sites during normal sinus rhythm;

25 FIGURES 3A, B and C show electrograms obtained  
under simulated ventricular tachycardia conditions;

FIGURE 4 shows the electrograms obtained at the  
four sites under conditions of ventricular fibrillation;

30 FIGURE 5 is a block diagram of a cardiac implant  
embodying this invention; and

FIGURE 6 is a flow diagram indicating the  
characteristic operation of the present invention.

The feasibility of automatic recognition of  
ventricular tachycardia and ventricular fibrillation has  
35 been examined in a number of patients undergoing coronary  
artery surgery. Bipolar epicardial electrograms from  
four discrete points on the surface of the heart have

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1 been recorded during operation. The points are  
indicated on the ventricles of the heart. It has been  
observed that during normal rhythm, the points which are  
recorded are activated in a certain sequence which is at  
5 least consistent, although not always specific to that  
rhythm. Thus, referring to Figure 1 of the accompanying  
drawings, the locations of four discrete points numbered  
A, B, C and D on the left ventricle (LV) and right  
ventricle (RV) are shown, two of the points (A and D)  
10 being on the left ventricular and right ventricular  
apices and points B and C being at left ventricular and  
right ventricular paraseptal positions. A pacing site is  
located on the right ventricle adjacent the third point.  
During normal rhythm, activation took place in the  
15 sequence C, D, B, A in this particular case (see Figure  
2). Furthermore, the timing from the first detected  
deflection to the last of the four was always the same  
during normal rhythm and in this example, because of  
normal rhythm, the timing is short, being of the order of  
20 25 msec.

With abnormal rhythm, this timing will generally  
be increased and the sequence of activations changed.

This latter observation was established by  
simulation of an abnormal rhythm by pacing from the site  
25 on the right ventricle. It was observed that 8 out of a  
group of 10 patients paced at this particular site showed  
a change of sequence of activation compared with that  
seen during normal sinus rhythm. Recording of the  
sequences obtained showed that activations change from C,  
30 D, B, A to C, B, D, A. Another abnormality which was  
induced was that because a normal conducting system was  
not utilised, the spread of activity took longer across  
the heart so that the timing from the onset of  
depolarisation detected first at site C and finally at  
35 site 1 took 85 msec as opposed to 25 msec. Figures 3A,  
3B and 3C indicate that this duration and sequence of  
activation is not affected by the rate of the abnormal

1 rhythm provided that its site of origin remains constant.  
2 Maintaining the same set of sites, further  
3 experimentation to induce ventricular fibrillation  
4 yielded further results of interest. Ventricular  
5 fibrillation was induced by putting AC current onto a  
6 heart under cardiopulmonary by-pass (this is a means of  
7 obtaining cardiac arrest and often used during surgery).  
8 It was observed that during ventricular fibrillation, the  
9 electrical activity at all four sites was extremely  
10 rapid, and certainly more rapid than normally seen.  
11 However, there was no apparent fixed sequence of  
12 activation. The activity can therefore be described as  
13 asynchronous. Because of the asynchronous nature of  
14 activity, there can be no fixed duration of activity.  
15 This thus provides a means of using multi site testing to  
16 distinguish between ventricular tachycardia where there  
17 is likely to be an altered sequence of depolarisation  
18 compared with normal rhythm and an increased duration of  
19 activation over that occurring during normal sinus  
20 rhythm, and ventricular fibrillation when all this  
21 synchrony is lost and the electrical activity from  
22 different points in the heart becomes asynchronous.

23 Thus apparatus embodying this invention is  
24 programmed to respond to ventricular tachycardia or  
25 ventricular fibrillation when they are detected from an  
altered sequence and duration of ventricular activation  
as detected by impulses sensed from the epicardial  
sensing sites.

26 The present invention is of particular value in  
27 that ventricular fibrillation has so far been a very  
28 difficult rhythm to detect reliably automatically.  
29 Moreover, the energy required by an implantable device to  
30 treat ventricular fibrillation is likely to be higher  
than that required to treat ventricular tachycardia.  
31 Therefore by the use of this technique, lower energies  
32 can be selected for termination of ventricular  
33 tachycardia thereby prolonging battery life. There is

1 thus provided a reliable method for the first time of  
detecting ventricular fibrillation. The micro-computer  
utilised in the circuit for comparing activation sequence  
with that during sinus rhythm can then control a  
5 defibrillator which can be discharged when rhythm  
characteristic of ventricular fibrillation or ventricular  
tachycardia is detected. Appropriate software is  
provided for controlling the micro-computer.

Finally Figures 5 and 6 show practical embodiments  
10 of the invention and should be viewed in conjunction with  
each other. Thus an implant 1 which has sensors (not  
shown) at positions such as shown in Figure 1) will  
monitor heart rate beat at all times using a normal heart  
beat detector 2 having time base and backup pacing  
15 control 4 whose operation is directed by a microprocessor  
5 having a memory 6. Should a high heart rate be  
detected, then a detector 3 which is normally operating  
in backup mode is switched on and simultaneous  
multi-channel sensing is carried out although Figure 1  
20 shows that sensing at four sites is carried out, and this  
number is adequate in general, there is no reason why  
more or less than four sites may be used for testing,  
although the use of four sites has been found to be an  
optimum compromise between cost and sensitivity. The  
25 microcomputer 5 which is utilised with the detector and  
receives signals therefrom will check by means of memory  
6 whether activation sequence and duration are compatible  
with sinus rhythm. If this is the case, then no action  
will be required. However, if the activation sequence  
30 and duration are not compatible with sinus rhythm, then  
provided that an activation sequence is synchronised  
indicating ventricular tachycardia, a response  
appropriate to treatment of ventricular tachycardia will  
be initiated, i.e. stimuli will be delivered by pulse  
35 generator 7. In certain cases, which depend on the type  
of tachycardia, however, ventricular tachycardia may be  
located by a relatively low energy shock for an

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1 associated defibrillator 8. If the activation sequence  
is not synchronised, indicating that ventricular  
fibrillation is taking place then operation of the  
defibrillator 8 will take place.

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1 Claims:

1. Apparatus for the automatic recognition of ventricular tachycardia and ventricular fibrillation characterized by:
  - 5 at least two sensors (A,B,C,D) for attachment of at least one sensor to each ventricular epicardial surface of a heart;
  - 10 signal paths connecting the sensors to programmed means (2,5,6) for detecting a pulse sequence representing the ventricular electrical activity of the heart and for comparing the pulse sequence detected with that representing the electrical activity of the heart during normal ventricular rhythm of the heart; and
  - 15 means for converting the detected pulse sequence into a form which will be useful for providing a corrective response to a pulse sequence representing the electrical activity of the heart during abnormal ventricular rhythm of the heart.
2. Apparatus as claimed in Claim 1, which 20 additionally comprises means (7,8) for supplying to the heart stimuli to restore normal rhythm thereto following identification of abnormal ventricular rhythm.
3. Apparatus as claimed in claim 2, wherein said heart stimuli supplying means (7,8) is adapted to supply 25 less energetic heart stimuli in the event of ventricular tachycardia identification than in the event of ventricular fibrillation identification.
4. Apparatus as claimed in Claim 1, additionally comprising means for converting the detected pulse 30 sequence into a readable form.
5. Apparatus as claimed in Claim 1, wherein for any predetermined arrangement of the sensors on the ventricular epicardial surfaces, the programmed means (5,6) is programmed to detect the time interval occupied 35 by a predetermined number of pulses and the sequence of activations, both of which detected parameters are compared by the programmed means with the

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1 same parameters when determined during normal rhythm of  
the heart.

6. Apparatus as claimed in Claim 5, wherein the  
programmed means (5,6) is programmed to detect  
5 asynchronous electrical activity at said heart surfaces.

7. Apparatus as claimed in Claim 1, which  
comprises four sensors (A,B,C,D) for application two to  
each of the two ventricles of the heart.

8. Apparatus as claimed in claim 7, wherein two  
10 of the sensors (A,D) are for application to the left  
ventricular and right ventricular apices and the other  
two sensors (B,C) are for application to the left  
ventricular and right ventricular paraseptal positions.

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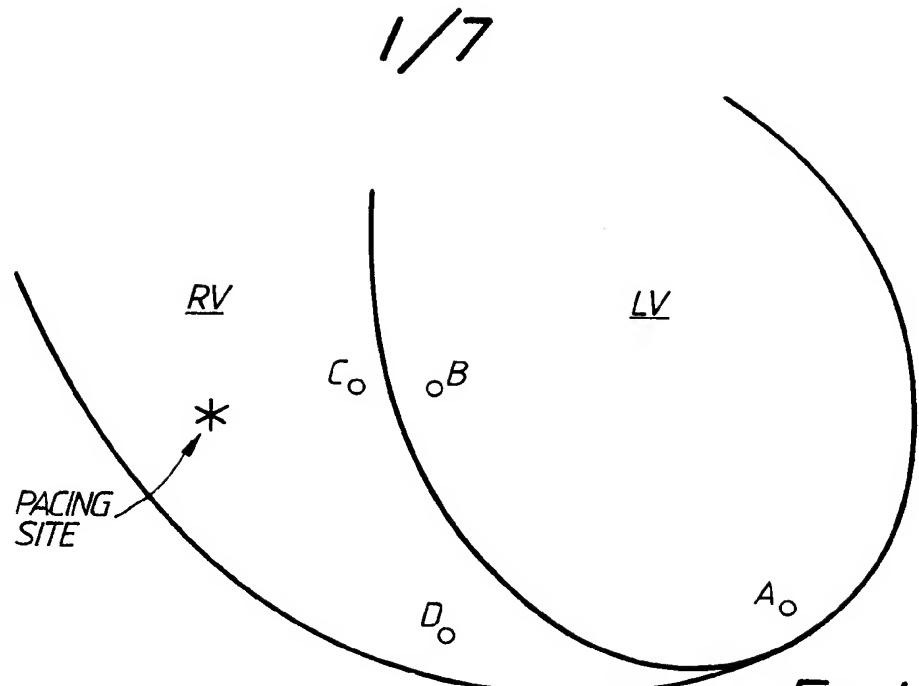


FIG. 1.

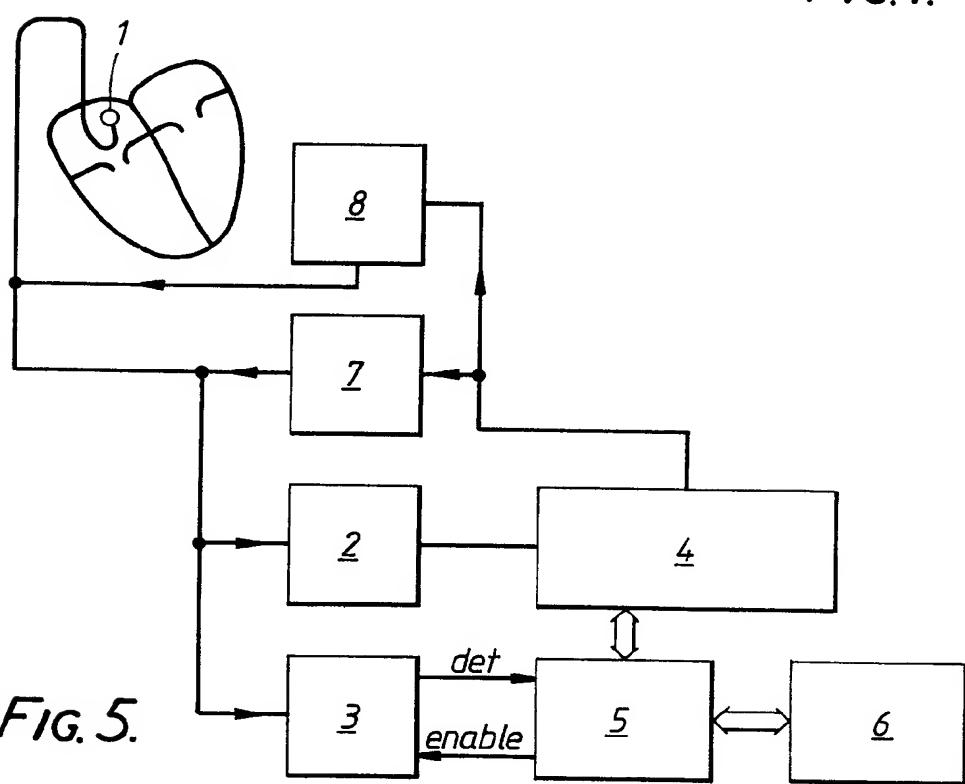


FIG. 5.

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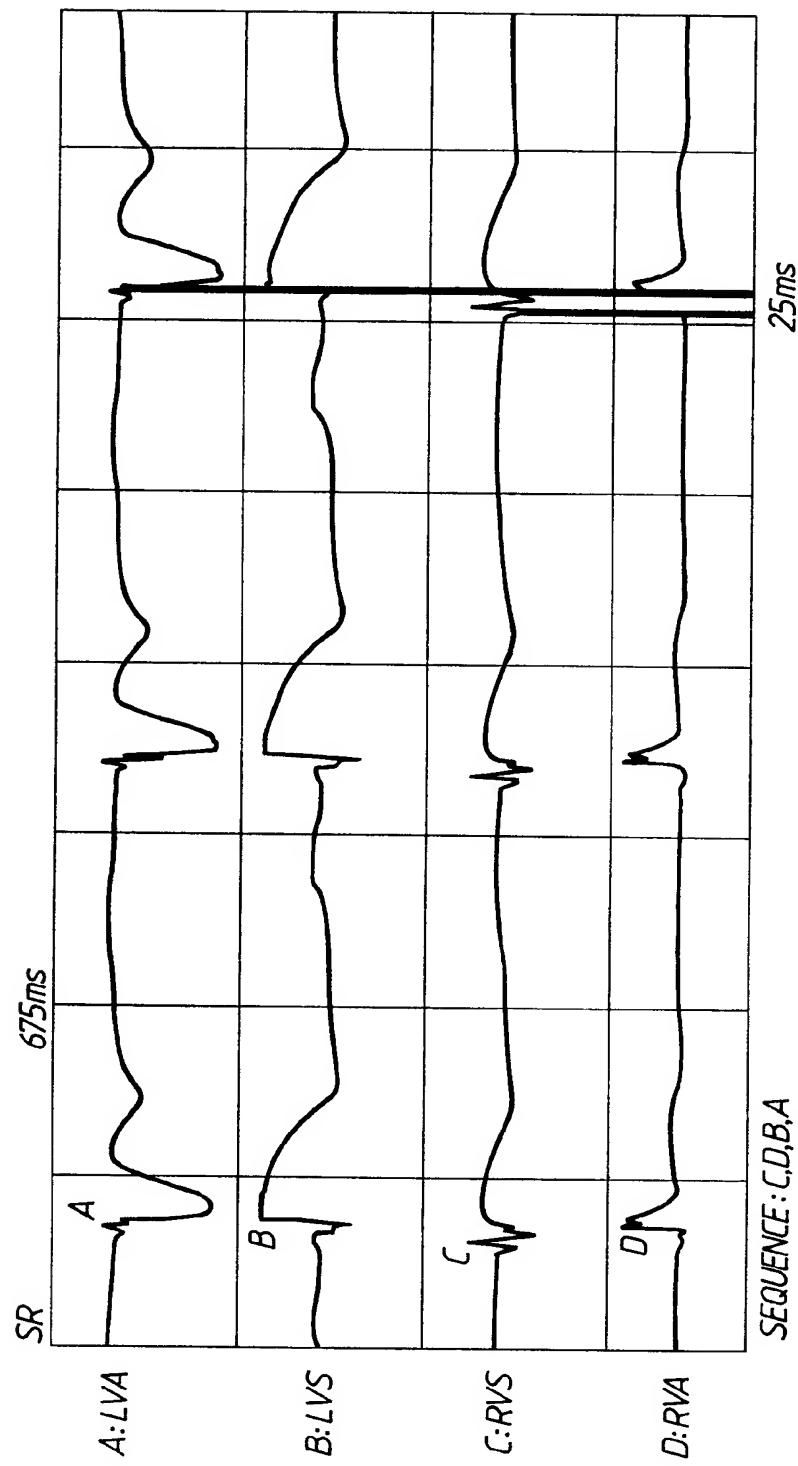


FIG. 2.

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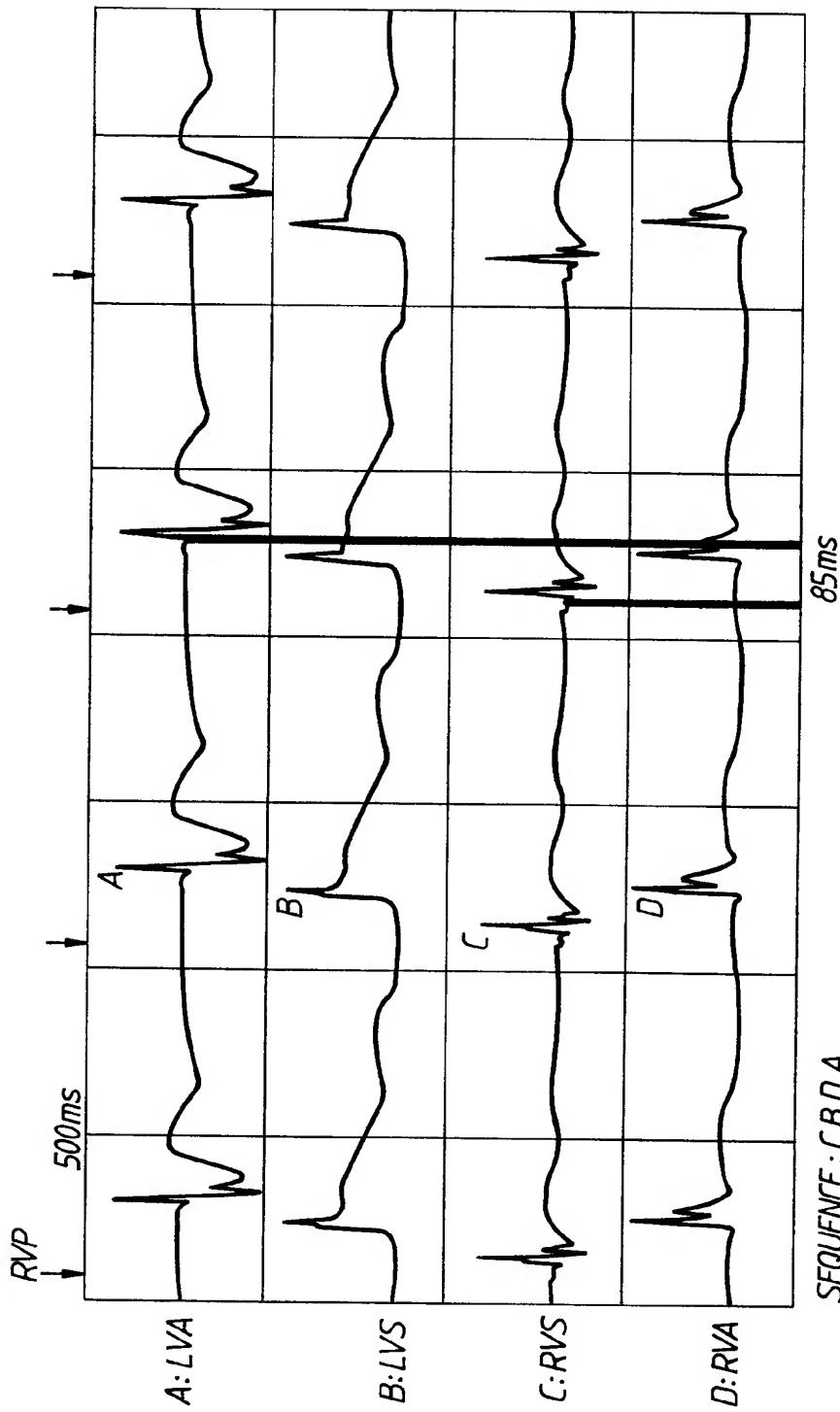


FIG. 3A.

SEQUENCE : C,B,D,A

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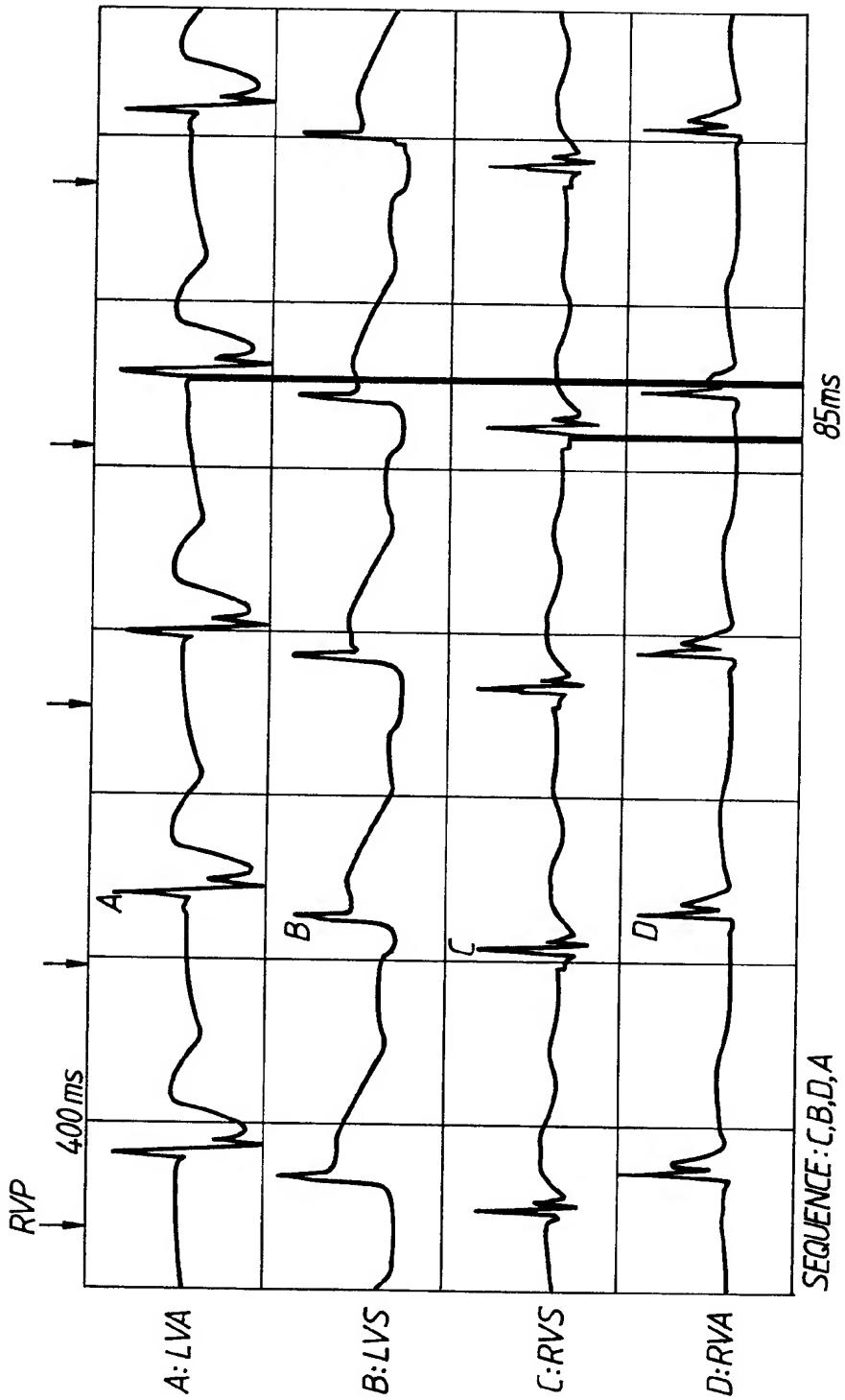


FIG. 3B.

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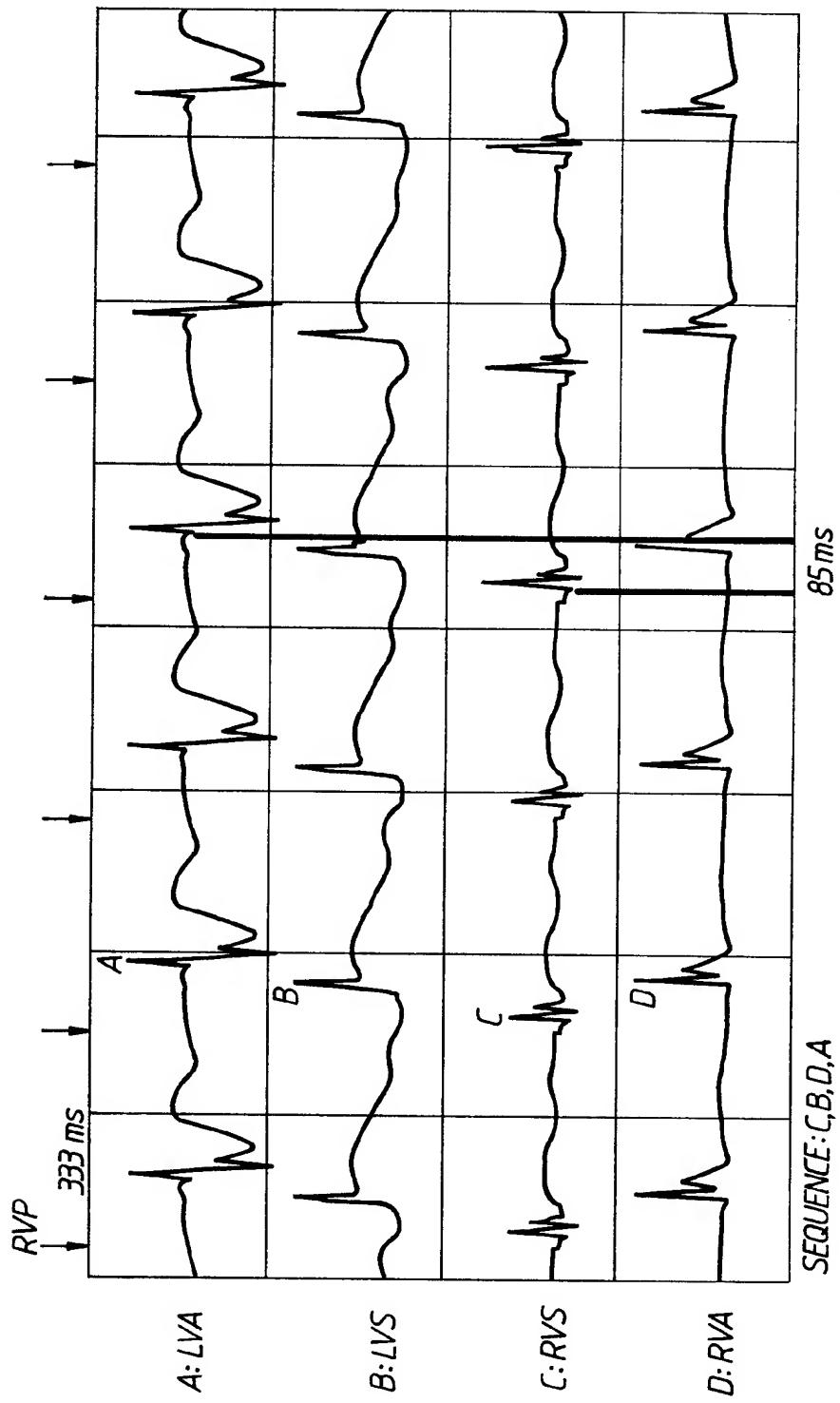


FIG.3C.

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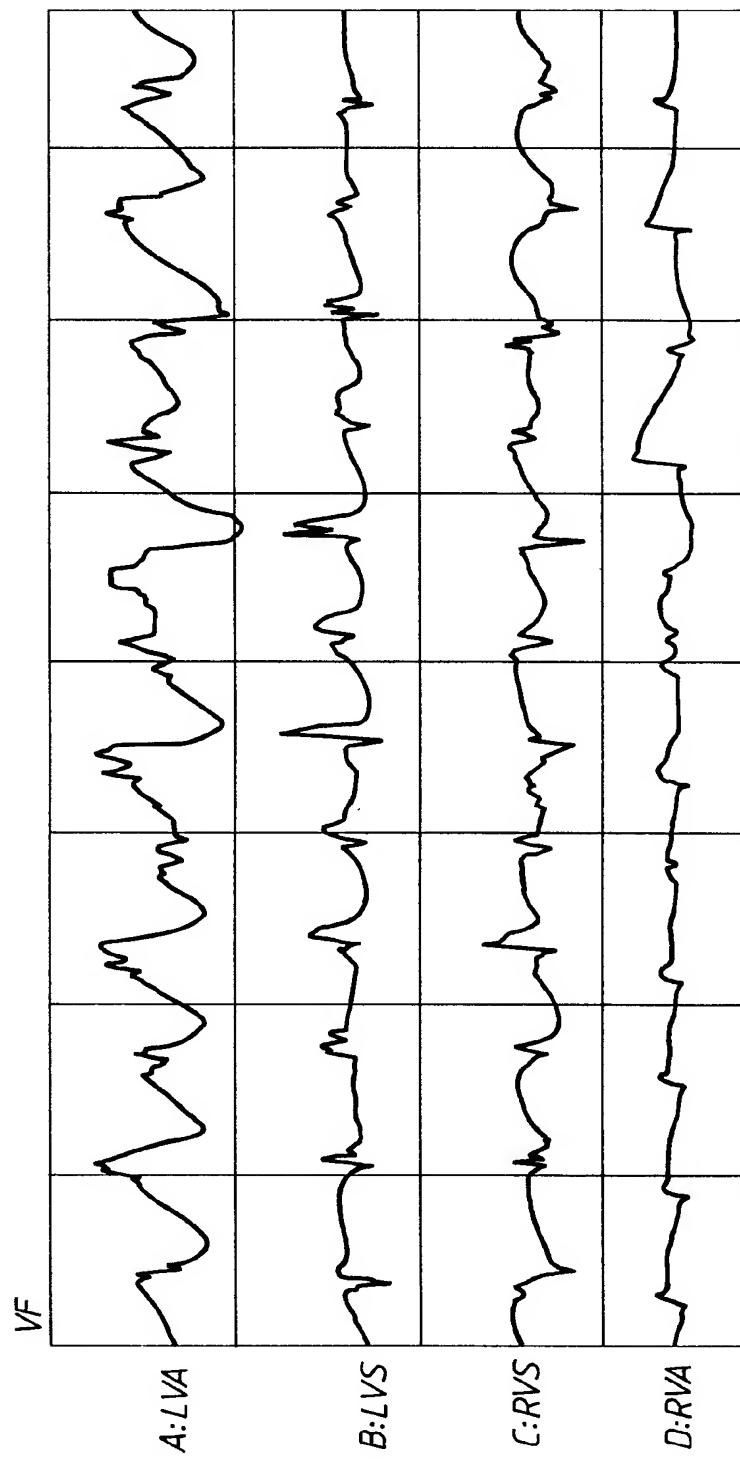


FIG.4.

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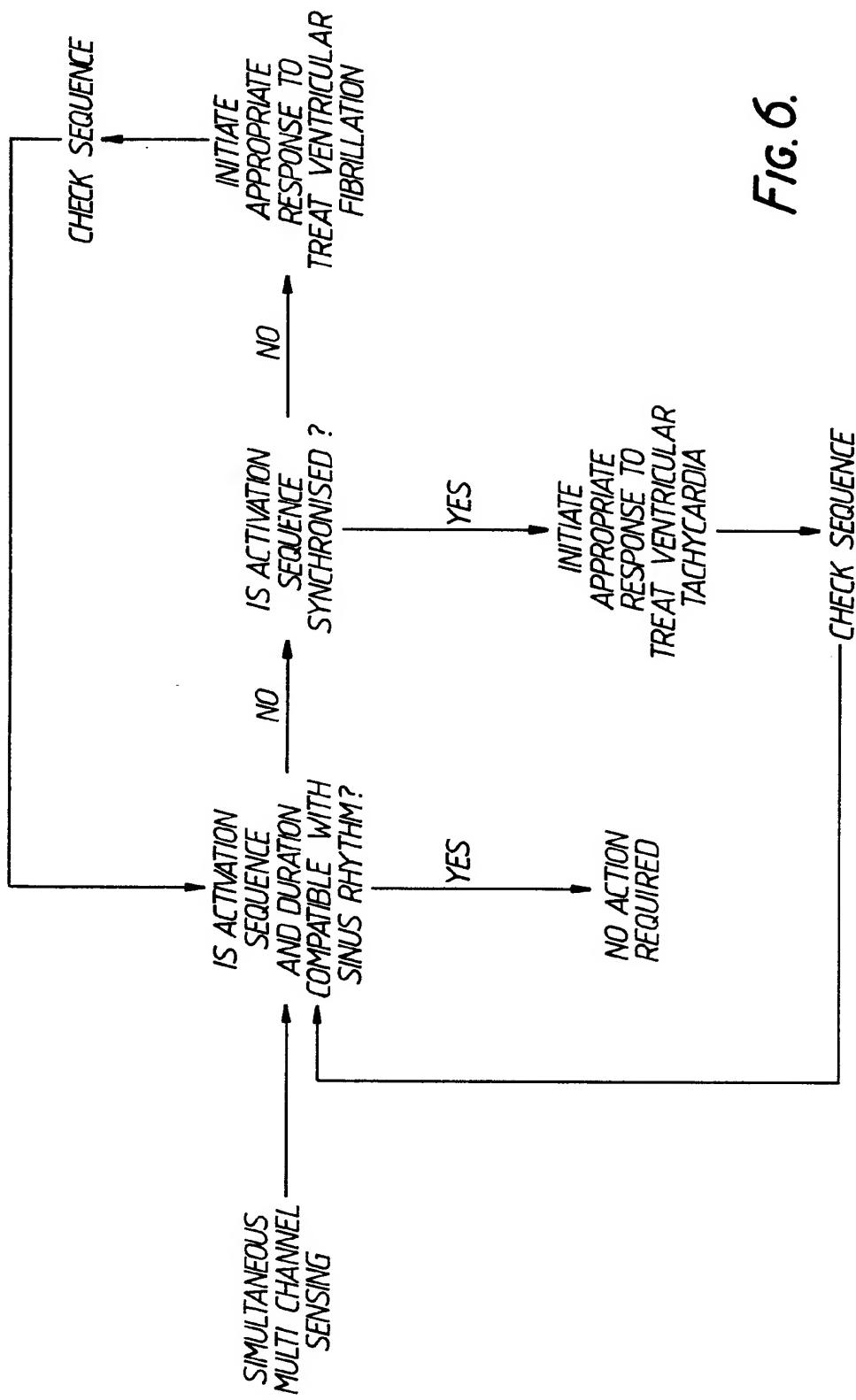


FIG. 6.



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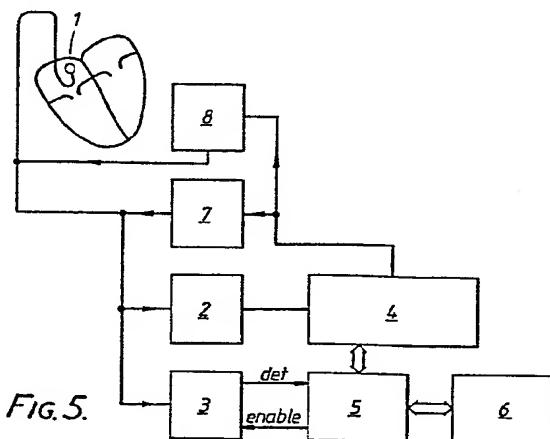


FIG. 5.



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	WO-A-8 200 415 (MIROWSKI) * Abstract; page 4, line 1 - page 6, line 21 *	1-3	A 61 N 1/36 A 61 N 1/38
Y	--- EP-A-0 001 708 (MEDTRONIC) * Page 4, line 12 - page 5, line 18; page 10, line 1 - page 11, line 8 *	1-8	
A	--- US-A-4 432 375 (ANGEL) * Abstract; claims 1-3 *	1-3	
Y	--- IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, vol. BME-29, no. 5, May 1982, pages 359-361, IEEE, New York, US; A.R.S. BUKHARI et al.: "Cardiac arrival time analyzer" * Whole document *	1-8	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	--- PROCEEDINGS OF THE IEEE, vol. 67, no. 9, September 1979, pages 1322-1337, IEEE, New York, US; L.J. THOMAS Jr. et al.: "Automated cardiac dysrhythmia analysis" * Abstract; figures 1-2 *	---	A 61 B A 61 N
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	29-09-1987	DELEU A.J.H.	
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone	T : theory or principle underlying the invention		
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